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EXPERIMENTAL STUDY OF CONVENTIONAL ENERGY DETECTOR FOR SPECTRUM SENSING

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ABSTRACT

For efficient utilization of the radio Spectrum, a frequency reuse schemes that is cosistent with the objectives of increasing capacity and minimizing interference is required. To understand efficient use of radio Spectrum, Cognitive radio arises with enticing solution to the spectral congestion problem by introducing opportunistic usage of the frequency bands that are not heavily occupied by licensed users. Spectrum sensing is signal detection mechanism in order to identify occupied and vacant frequency bands and hence to detect the availability of the vacant spectra. This paper gives information about one of the method of spectrum sensing ie.conventional energy detector and also discuss about the flow and parameters of the energy detection method. It proposes simulation results of system parameters and also analyzed their relationship with each other during signal detection processs.

KEYWORDS: Spectrum Sensing, Threshold Energy, Probability of Detection (Pd), Probability of False Alarm (PFA)

I. INTRODUCTION

***C**ognitive **R**adio* (CR) is an adaptive, intelligent radio, and network technology that can automatically detect available channels in a wireless spectrum and change transmission parameters such as transmission power and transmission frequency band, based on the environment. In a CR network, ordinary wireless devices are referred to as primary users (PUs), and CRs are referred to as secondary users (SUs). [8]

CR is defined as "An intelligent wireless communication system that provides more efficient communication by allowing secondary users to utilize the unused spectrum segments".From the definition, the main functionalities required for the cognitive radio systems can be summarised as follows:

- **Spectrum Sensing**: Sensing and monitoring the available spectrum bands reliably to detect the unused portion of the primary user spectrum.
- **Spectrum Decision**: The cognitive radio can allocate a channel based on the regularly policies and spectrum sensing results.
- **Spectrum Sharing**: Coordination among multiple cognitive radio users is needed to pre-vent the colliding in the available portion of the spectrum.
- **Spectrum Mobility**: The cognitive radio user is regarded as visitor to the primary user spectrum, and a reliable communication cannot be sustained for a long time if the primary user uses the licensed spectrum frequently. Therefore, the cognitive radio system should support mobility to continue the communication in other vacant bands.

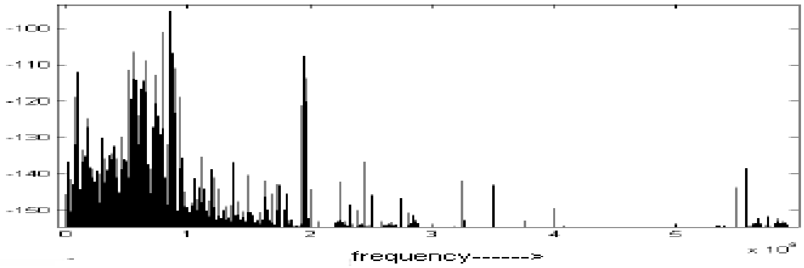

Figure 1: Measurement of Spectrum Utilization (0-6 Ghz)

The Federal Communications Commission’s (FCC) frequency allocation chart indicates overlapping allocations over all of the frequency bands, which reinforces the scarcity mindset [3]. Figure 1 shows the power spectral density (PSD) of the received 6 GHz wide signal collected for a span of 50ms sampled at 20 GS/s. This view is supported by recent studies of the FCC’s Spectrum Policy Task Force who reported vast temporal and geographic variations in the usage of allocated spectrum with utilization ranging from 15% to 85% [1]. In order to utilize these spectrum ‘white spaces’, the FCC has issued a Notice of Proposed Rule Making (NPRM – FCC 03-322) [2]. advancing Cognitive Radio (CR) technology as a candidate to implement negotiated or opportunistic spectrum sharing.

Cognitive radio (CR) technology is a new way to compensate the spectrum shortage problem of wireless environment. It enables much higher spectrum efficiency by dynamic spectrum access [1]. It allows unlicensed users to utilize the free portions of licensed spectrum while ensuring no interference to primary users’ transmissions. Spectrum sensing [5] is the most important task among above function for the establishment of CRs because they need to sense the spectrum band for a spectrum hole [5-9], decide to use the spectrum band or not. A number of different techniques have been proposed for identifying the presence of the PU signal transmission. Spectrum sensing techniques can be broadly divided into following methods:

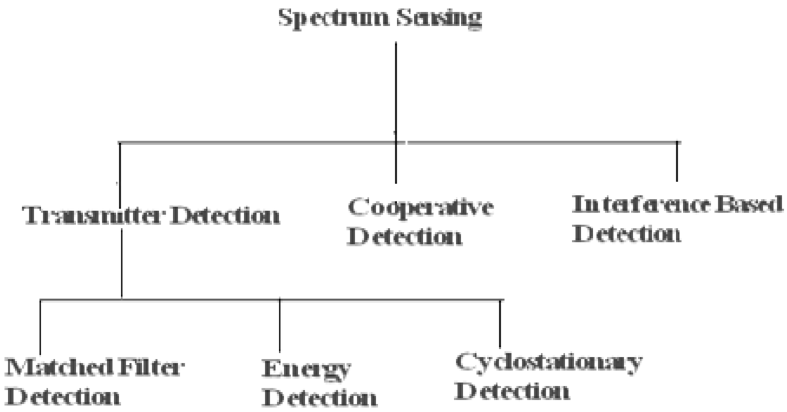

Figure 2: Techniques of Spectrum Senisng

In this paper we discussed about conventional energy detection technique to view its performance in sensing. This paper is organized as follows: Section 2 Explains the Energy detector and its signal flow. Section 3 Describes Parameters, Section 4 Simulation Result and Discussion, Section 5 Conclusion is drawn, Section 6 References.

II. ENERGY DETECTION TECHNIQUE

Conventional Energy detection is a the quit simple. The detector computes the energy of the received signal and compares it to certain threshold value to decide whether the desired signal is present or not. When the primary user signal is unknown or the receiver cannot gather sufficient information about the primary user signal, the energy detection method is used. This method is optimal for detecting any unknown zero-mean constellation signals and can be applied to cognitive

radios (CRs). The energy detector consists of a square law device followed by a finite time integrator. The output of the integrator at any time is the energy of the input to the squaring device over the interval *T*. The noise pre-filter serves to limit the noise bandwidth; the noise at the input to the squaring device has a band-limited, flat spectral density. [3]

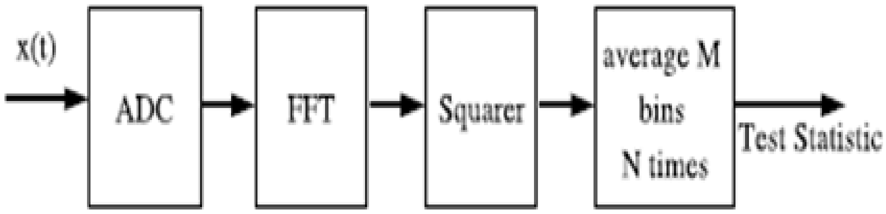

Figure 3: Frequency Domain Representation of Energy Detection Mechanism

In order to measure the signal energy, the received signal is first sampled, then converted to frequency domain taking FFT followed by squaring the coefficients and then taking the average. The decision making strategy of energy detector is the test of two hypotheses *H*0 and *H*1. The detection is a test of the following two hypotheses:

Ho: The input y(t) is noise alone

- y(t)=n(t)
- E [n(t)]= 0
- Noise spectral density = N0, (two-sided)
- Noise bandwidth = W cycles per second.

H1 : The input y(t) is signal plus noise :

- y (t)=s(t)+n(t)
- E [s(t)+n(t)]=s(t)

The received signal r(t): r(t)=h s(t)+n(t) Where h =0 or 1 under hypotheses or, H 0, H1

FLOW OF CONVENTIONAL ENERGY DETECTION METHOD

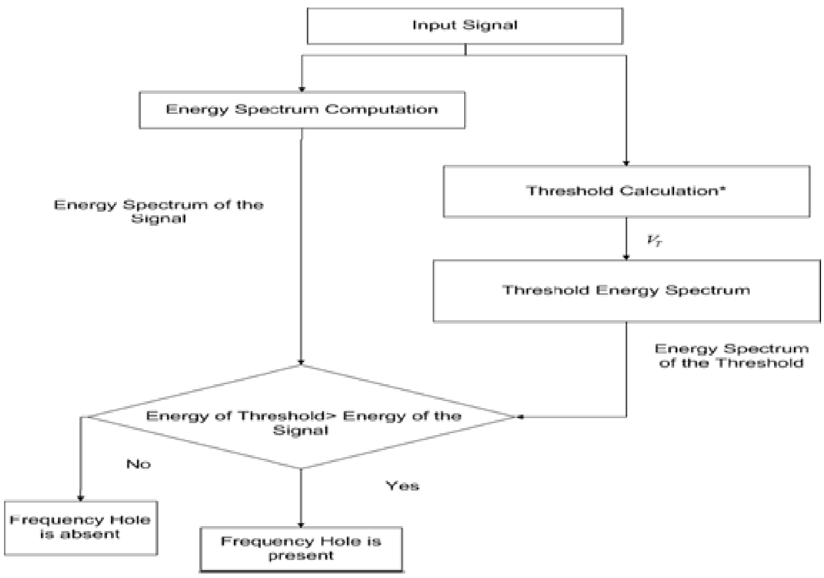

Figure 4: Flow of Energy Detector

FLOW OF ENERGY SPECTRUM COMPUTATION

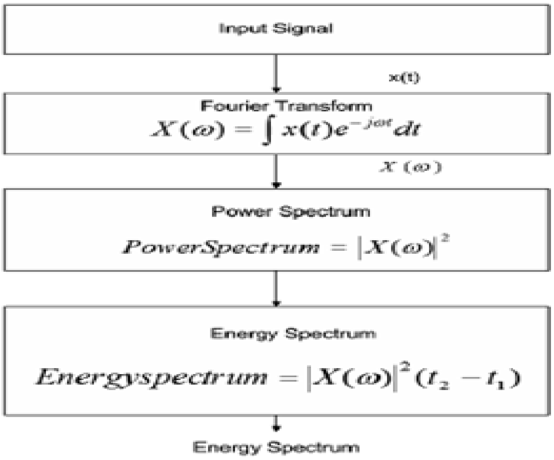

Figure 5: Flow of Energy Spectrum Computation

CALCULATION OF THRESHOLD ENERGY SPECTRUM

The energy detection method calculates the energy of the input signal and compares it with a Threshold energy value. The signal is said to be present at a particular frequency if the energy of the signal exceeds the Energy level of the threshold.The threshold value is chosen so as to control the parameters such as probability of false alarm and probability of detection,The threshold voltage can be calculated from:

$$V_{TH} = \sqrt{2\sigma_n^2\, ln\left(\frac{1}{P_{FA}}\right)}$$

III. SYSTEM PARAMETERS

Our fundamental objective is to use the system the decision making process for the availability of the spectrum holes, record the data and then carry out simulations to analyze the stored data [3] [4]

Probability of Detection (Pd)

- The probability of detection is the time during which the PU (licensed) is detected. The throughput of system depends upon Pd.
- If the sensing time is increased then PU can make better use of its spectrum and the limit is decided that SU can’t interfere during that much of time.
- More the spectrum sensing more PUs will be detected and lesser will be the interference because PU can make best use of their priority right.

$$P_D = \int_{V_{TH}}^{\infty} \frac{1}{\sqrt{2\pi\sigma_n^2}}\, exp\left(-\frac{v^2+V_0^2}{2\sigma_n^2}\right) dv$$

Probability of False Alarm(PFA)

Probability of the sensing algorithm mistakenly detecting the presence of PUs while they are inactive. Low probability of false alarm should be targeted to offer more chances for SUs to use the sensed spectrum.

$$P_{FA} = \int_{V_{TH}}^{\infty} \frac{1}{\sqrt{2\pi\sigma_n^2}}\, exp\left(-\frac{v^2}{2\sigma_n^2}\right) dv$$

Receiver Operating Characteristic (ROC)

In general, if both of the probability distributions for detection and false alarm are known, the ROC curve can be generated by plotting the Cumulative Distribution Function (area under the probability distribution from -inf to +inf) of the detection probability in the y-axis versus the Cumulative Distribution Function of the false alarm probability in x-axis.

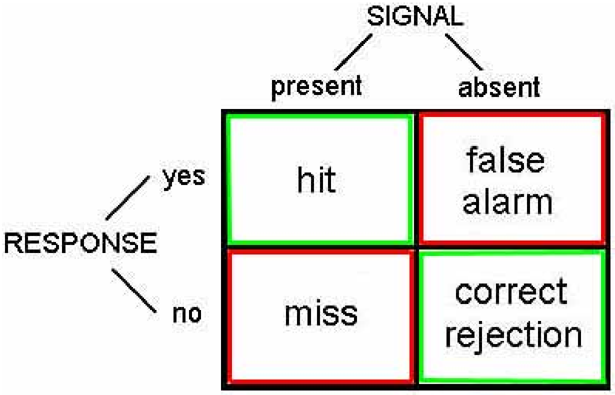

Figure 6: Signal and Détection Response by the System

The following probabilities of interest can be defined:

Probability of Detection, *PD* : The probability that a target is declared (i.e., *H*1 is chosen) when a target is present (hit condition)

Probability of False Alarm, *PFA*: The probability that a target is declared (i.e., *H*1 is chosen) when a target is *not* present (False alarm)

Probability of Miss, *PM* : The probability that a target is *not* declared (i.e., *H*0 is chosen) when a target is present (miss condition)

Note that $PM = 1 - PD$. Thus, *PD* and *PFA* be sufficient to specify all of the probabilities of interest. As the latter definitions imply, it is important to realize that, because the problem is statistical, there will be a finite probability that shows the decisions.

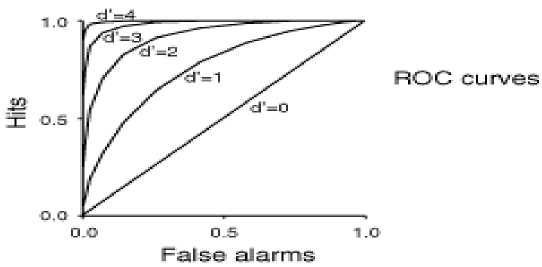

Figure 7: Standard Characteristics of Detectors for Different Values of Receiver Operating Curves (ROC) Represent Detection Probabilities (Pd) as A Function of SNR for A Given False-Alarm Rate(PFA)

IV. SIMULATION RESULT AND DISCUSSIONS

The authors' ongoing research activities regarding spectrum sensing for cognitive radio system is on process, to implement the ideas in real scenario a lot of work is yet to be done. The main target of this work is to perform experimental study which shows the feasibility and practical performance of the energy detector approach under real noise and interference conditions in wireless channels.

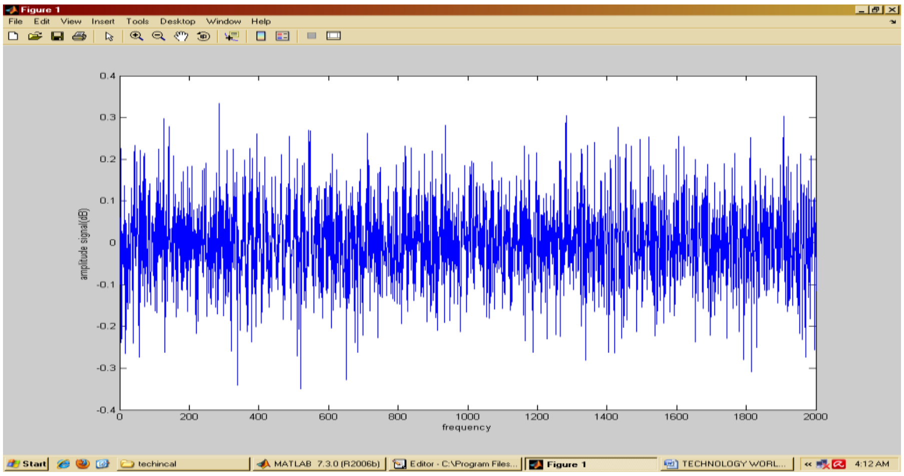

Figure 8: Transmitted Signal

The above figure 8 shows the single channel signal, consist of single tone passes through AWGN channel and acts as a received signal. The primary receiver after capturing single tone it under goes signal processing and analysis to determine vacant spectra. The Neyman-Pearson detection rule [5] will be used for deciding an optimal choice between our two hypotheses. (*H*0 or *H*1) Under these rules, the decision process is designed to maximize the probability of detection *PD* under the constraint that the probability of false alarm *PFA* does not exceed a set constant.

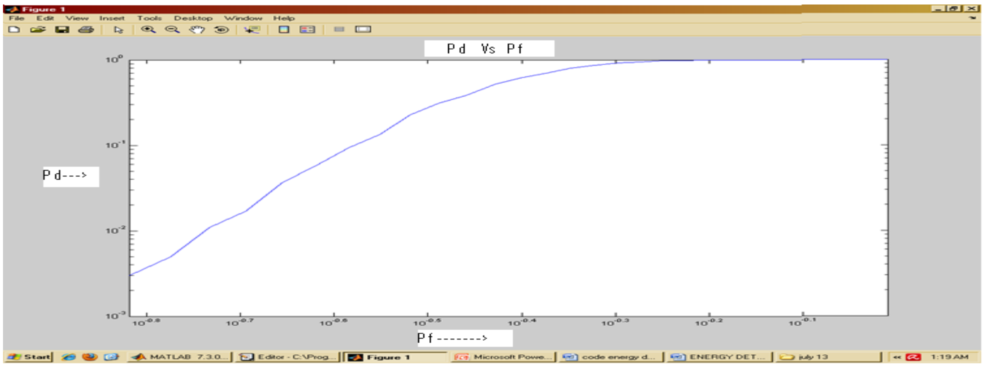

Figure 9: Probability of Detection vs Probability of False Alarm

In this paper, authors focus on Parameters Pd and PFA of energy detector and also plot a graph between Pd Vs PFA and discussed their effects on users. However, it will be seen that for a fixed system design, increasing in *PFA* implies increasing in *Pd*. In Figure 7 shows that ROC of spectrum sensing for different number of probability of false alarm under AWGN channel where time bandwidth factor 1000 is used. The probability of detection is measured in figure 9 based on the probability of false alarm. It shows that probability of detection is based on PFA and range for PFA used is from 0.01 to 1 by increasing 0.02.

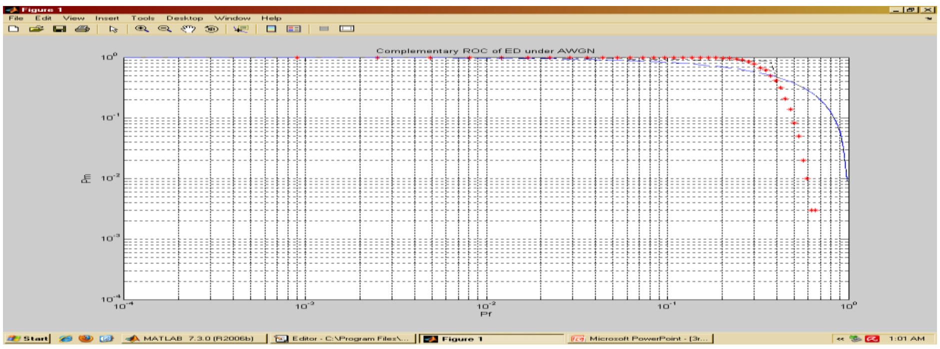

Figure 10: Probability of False Alarm vs Probability of Miss

In the above Figure 10 plot shows the value of PFA. =10^-2.As we know that when PFA increases the Pd also keep on increasing but Pm = (1-Pd). So, Pm goes on decreasing. We have made two plots one is for single Channel indicated by continuos line and dotted line is for multiple channels I.e. indicated by red color. we can see from this Figure that when PFA=10^-3, Pm=10^0;at PFA =10^0, Pm =10^-2 in case of single channels but in case of multiple channel, when PFA=10^-3, Pm=10^0;at PFA =10^0, Pm =10^-25.It is clear from this plot that in case of multiple channels miss rate is fast as compare to single channel. It shows that when there is single user the detection becomes easy as compare to multiple channels.

V. CONCLUSIONS AND FUTURE WORK

In this paper, firstly, we discussed about the spectrum sensing and then energy detection method. Using MATLAB (R2006a), we build up the conventional energy detector and studied parameteric relation. It relies on comparing the energy of a threshold with that of the received signal in a real time window. A “hole” is said to be present at a particular frequency if the energy of the threshold is greater than the energy of the signal. When PFA is increasing Pd is also increasing. As we can see that when false alarm is high i.e. 10^-2 then probability of detection becomes high. It shows that probability of detection is based on PFA. This technique development opens the door for building up of cognitive radio system using more advanced spectrum sensing methods like cooperative spectrum sensing and eigenvalues detection with energy detection as their basis.

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